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LIFE SCIENCE EXPERIMENTS DURING PARABOLIC FLIGHT:
THE MCGILL EXPERIENCE

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Over the past twelve years, members of the Aerospace Medical Research Unit of McGill University have carried out a wide variety of tests and experiments in the weightless condition created by parabolic flight. This paper discusses the pros and cons of that environment for the life scientist, and uses examples from the McGill program of the types of activities which can be carried out in a transport aircraft such as the NASA KC-135.

Au cours des douze dernières années, certains membres de l'Unité de Recherches en Médecine Aérospatiale de l'Université McGill ont complété une grande variété de tests et d'expériences dans une condition d'apesanteur créée par un vol parabolique. Ce document présente les pour et les contre de ce milieu pour le scientifique spécialisé dans ce domaine et emploie des exemples du programme de McGill pour démontrer le genre d'activités qui peuvent être engagées dans un avion de transport comme le KC-135 de la NASA.

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INTRODUCTION

On or near the surface of Earth, a state of weightlessness can only be achieved by accelerating at an appropriate and constant rate toward the center of the planet. For the life scientist studying higher species including man, this allows three options. The first is very short duration vertical falls, with controlled deceleration prior to impact. For all practical purposes, the result is less than 1 sec of weightlessness. This is not particularly useful, unless one is studying very rapid events such as vestibulospinal reflexes caused by the sudden transition into zero-g. Another option is orbital space flight, where the duration of weightlessness is measured in days. In most cases, however, several hours will elapse between launch and initial experiments. Lying between these two extremes is parabolic flight in an aircraft. While conceptually nothing more than a vertical fall with an added steady horizontal velocity, the duration is increased greatly by falling first up and then down like a ball tossed into the air, and by using thousands of feet of altitude to "catch" the contents of the aircraft after each maneuver. As a result, up to 25 sec of microgravity is possible in sub-sonic aircraft, and up to 45 sec in a high-performance fighter. Furthermore, experiments can begin within seconds of reaching the weightless condition, a vital consideration if the system under study adapts rapidly to weightlessness.

USES OF SHORT-DURATION WEIGHTLESSNESS

The usefulness of short periods of weightlessness extends beyond the scientific experiments which can be performed under these conditions.

Tests of equipment

It is always necessary to prove that hardware to be used during space flight will function normally in a zero-g environment. In many cases, careful design, analysis and ground-based testing will be adequate. In some situations, however, a more direct demonstration may be appropriate, and certain equipment prepared for Canada's first medical experiment in space provides a good example. For this study, a torso harness and elastic cords were designed to provide a footwards force allowing subjects to hop and fall in weightlessness. To vary that force, three sets of three bungees were used, with one, two or three of each set anchored to the floor at various times. Handling problems were anticipated, but the mechanical behavior of the equipment would have been difficult to model with any degree of confidence. One flight provided more than ample evidence that the materials used were far too soft and flexible (Figure 1). Stiffer webbing was substituted for the harness and bungee adjusting straps, and they performed well when used subsequently in six different experiments on Spacelab missions SL-1 and D-1.

Development of methods

Volume, mass, energy and timeline limitations in Shuttle encourage the development of simplified methods to perform otherwise routine measurements. In many instances, this leads to unique approaches which can only be evaluated in weightlessness. An important test of human inner ear function involves rotating the subject and measuring resulting eye movements generated by vestibulo-ocular reflexes. In Figure 2, the author is seen assisting M.I.T. colleagues L.R. Young and C.M. Oman in an early attempt to measure eye movements in a free-floating and spinning subject. As it turned out, this test demonstrated that it was necessary

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to control the axis of rotation more precisely, leading through several stages to the design and construction of a sophisticated human rotator for use in Spacelab.

Astronaut training

Medical experiments in space are nearly always carried out by astronaut crewmembers who have little or no previous exposure to the specific area of study. Careful preflight training is necessary if they are to perform all of their tasks (as operator and as subject) successfully, and this often includes the learning of specific physical skills. Sometimes the latter require practice during parabolic flight. In Figure 3, Spacelab-1 Mission Specialist Owen Garriott is seen learning to hop in weightlessness, using the harness and elastic cords referred to earlier. This is not particularly difficult, but correct technique did have to be learned before launch, under the direct guidance of the Principal Investigator. Once the method was learned, the remaining parabolas were used to collect physiological data on the acute effects of weightlessness on the vestibular system. These data complemented the measures of longer term effects obtained from the same astronauts on Shuttle.

Scientific experiments

While the development of space flight equipment and methods, and astronaut training are all important uses of parabolic flight, certain experiments can be justified solely on the basis of their potential contributions to basic knowledge. Many issues of gravitational biology can only be tested in weightlessness, and this includes the influence of gravity on human nervous system function. In Figure 4, the author is seen testing Spacelab-1 Payload Specialists Byron Lichtenberg and Ulf Merbold for motion sickness susceptibility shortly after their return from orbit. This experiment, developed by K.E. Money, determined that the adaptive changes which occurred in these astronauts' nervous systems during flight and which ended their early space motion sickness, carried over for several days after landing. This provided evidence as to the nature of these changes, and also confirmed that it is justifiable to study them immediately after as well as during flight.

ADVANTAGES OF PARABOLIC FLIGHT

For the life scientist studying the effects of weightlessness on biological systems, parabolic flight offers a number of advantages. Though far from inexpensive, the cost is still much less than that of an orbital experiment. In addition, the total man-hours of weightlessness available in aircraft are far greater than those provided by Shuttle. In part, this is responsible for the greatly reduced lead time for parabolic experiments compared to their orbital equivalents. Years of preparation can be reduced to months, which may determine if an experiment is feasible or not.

A particularly important feature is the ability of the investigator to conduct his own research in the aircraft. By way of contrast, even the most carefully trained astronaut in Shuttle will inevitably lack in-depth experience in most of the highly specialized areas of research assigned to a particular mission, and telescience (guidance from the ground) has not proven to be an entirely adequate substitute. Simply being exposed to the zero-g working environment is also of considerable value to the researcher who must design procedures to be carried out by others on Shuttle.

Finally, looking to the future, parabolic flight experiments provide an opportunity for student involvement in microgravity experimentation. For many reasons, graduate student programs cannot be centered about orbital experiments, making it difficult to train the next generation of space life scientists. Parabolic flight is a viable alternative, however, one which should be exploited more often in the future.

LIMITS AND PROBLEMS

There are also certain disadvantages to parabolic flight experiments which cannot be avoided. Compared to more conventional laboratory-based life science, the cost per experiment is likely to be higher. In addition, the time-consuming technical and administrative preparations required for each flight will limit the number of experiments which can be carried out per unit time.

More fundamental limits are imposed by the laws of physics. Each parabola provides a specific period of microgravity, and this time cannot be extended. The number of parabolas per flight is also limited by considerations such as high aircraft fuel consumption during these demanding maneuvers. Furthermore, weightlessness is always preceded by a period of hypergravity, as an upwards velocity is established.

Finally, the working environment in the aircraft is often less than ideal. Rather than being a criticism, this merely points out the limits of human beings and their technology in the real world of flight. Parabolas are not always perfectly flown, especially if the air is turbulent. The ambient noise level is high. Temperature and pressure fluctuate rapidly. Other activities in the aircraft create additional distractions. Finally, many passengers will become motion sick, especially if they move about during the pull-up phase of the parabolas.

CONCLUSION

Given the problems outlined above, is microgravity experimentation during parabolic flight a reasonable approach for those wishing to study the acute effects of removing gravity? If the questions being asked and the methods being used are appropriate for this special environment, our experience is that the aircraft provides a unique and valuable service. In many instances, the



Figure 1. Handling test of torso harness and bungee cords used on Spacelab missions SL-1 and D-1.



Figure 2. Measurement of vestibulo-ocular reflex in a free-spinning subject.

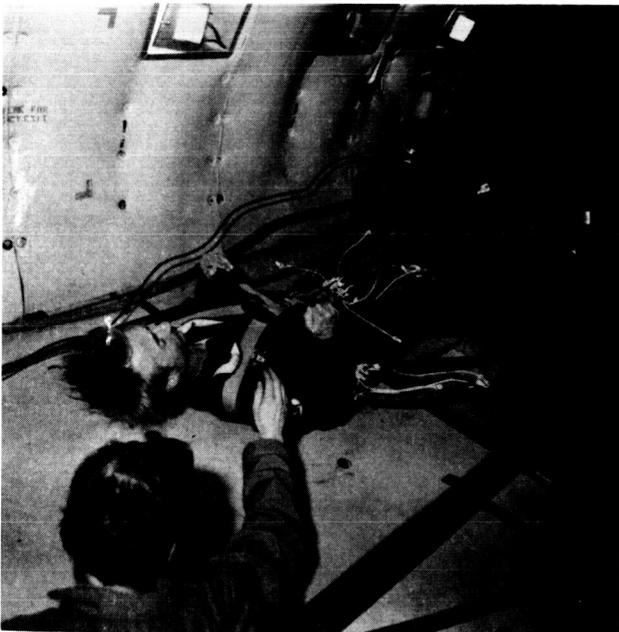


Figure 3. Learning to hop rhythmically on both feet in weightlessness.



Figure 4. Motion sickness provocative testing of Spacelab-1 Payload Specialists.

data which result simply could not have been obtained in any other way.

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